VI.—THE PHYSIOLOGY OF THE RETINA.

F. Boll. Zur Anatomie und Phys. der Retina. *Berliner acad. Monatsber.* 12th Nov., 1876, (abstr. in *Centralblatt f. d. med Wiss.* 31st March, 1877).—1. Zur Phys. des Sehens, etc. *Berliner acad. Monatsberichte,* 11th Jan. 1877; and (2) Nachträgliche Zusätze zu d. Mittheil. 15th Feb. 1877 (both in *Centralblatt.* 9th June, 1877).—Zur Anat. und Phys. der Retina. *Arch. f. Anat. und Phys. von Du Bois Reymond.* 1877, I. Heft. p. 4.

W. Kühne. Zur Photochemie d. Netzhaut. *Verhandl. d. naturhist. Vereins zu Heidelberg,* Jan. 1877; and *Revue Scientifique.* March 3d, 1877.—Vorl. Mittheilung über optographische Versuche. *Centralblatt.* 20th Jan., 1877.—Zweite Mitth. über Optogramme. *Centralblatt.* 27th Jan., 1877.—Ueber der Sehpurpur. *Centralblatt.* 17th May, 1877.—Ueber das Vorkommen von Sehpurpur. *Centralblatt.* 4th April, 1877.

Schenk und Zuckerkandl. Sehpurpur in Ange eines gehenkten Menschen. *Allgem. Wiener med. Zeitung.* 13th March, 1877.

Fuchs. Zur Farbe der Netzhaut. *Wiener med. Wochenschrift.* 10th Match, 1877.

Helfreich. Purpur der Retina. *Centralblatt.* 17th Feb., 1877.

Adler. *Centralblatt.* 7th April, 1877.

Dietl und Plenk. *Centralblatt.* 21st April, 1877.

Schmidt-Rimpler. *Centralblatt.* 9th June, 1877.

Michel. *Centralblatt.* 16th June, 1877.

Stef. Capranica. Phys-chem. Unters. über die farbigen Subst. der Retina. *Arch. f. Anat. und Phys.* 1877; II. and III. Heft. p. 282. (To be continued.)

Repeatedly statements have appeared by various authors—Leydig and others,—that the fresh retina of the frog and some other animals possesses a reddish tinge; but no further attention had ever been paid to this. It caused therefore great sur-

prise when Boll announced that the living retina is always *red*, and that this color is at once destroyed by exposure to light. This coloration, as Boll found, is limited to the external part of the retinal rods. A small number of rods, at least in the frog, are also of a bluish-green tint. This coloration of retinal rods seems to exist in all animals. Of invertebrates, Boll found it in the cephalopoda and anthropoda. Amongst vertebrates, he found it in all fishes and amphibia examined. In reptiles and birds, the colored oil globules of the retina interfere with its detection. In the retina of the lizard and snake (Coluber natrix), there are no rods, only cones; and, hence, the red color is not found (Kühne.) In the pigeon, Boll noticed a slight fading of the retina, when removed from the eye. In the falcon, Kühne found the red color absent behind the spots containing oil globules. The long rods of the owl (Athene noctua), however, show the greatest intensity of color, it being almost bluish or violet, and fading but very slowly on exposure to light. Of all mammals examined, Kühne failed in finding the red color only in the bat. The embryo of the calf has the external part of the rods colored as early as they exist. In man the *retinal red* was first seen by Schenk and Zuckerkandl in an executed criminal; soon afterward by Fuchs in the human fœtus. It has since been confirmed by Adler, Schmidt-Rimpler, and Kühne. Only Michel failed to find it in a normal eye, extirpated for orbital cancer, although he mentions all precautions as to the exclusion of light. The macula lutea was found by Schmidt-Rimpler to differ from the rest of the retina, it being of an orange tinge, in an extirpated eye, and dark brownish-red in fresh cadaver eyes. Kühne found the cones of the macula colorless in man and monkey, and the zone around it feebly colored, on account of the scarcity of rods. The zone bordering on the ora serrata was also but feebly colored; the ora itself colorless. Some queer statements have been made by Adler. In a blind eye he failed to detect the *retinal red*, though he used the same precautions, which enabled him to find it in other cases. In a case of retinal tumor, the red color was found in that part of the retina which had still perception of light, while the blind part was colorless. A retina, partially detached and prolapsed by an injury, was found uniformly red on examination with the light of a lamp; exposed to sunlight, the detached part lost its red color.

The color of the retina persists after death, if the eye is kept in darkness; it disappears after twelve hours in the rabbit, after about twenty-four hours in the frog. Its persistence in the extirpated eye on exposure to light is an index of vitality. In warm blooded animals light bleaches the retina left in situ in a few minutes; in extirpated eyes of the frog on the other hand the persistence of vitality is indicated by the persistence of the retinal red for many hours, although exposed to light. On removing the frog's retina it is at once bleached, hence the color-

ation of the retina *in situ* must be maintained by a *regeneration* of the color.

Boll describes four stages of the frog's retina after removal from the eye in bright daylight. In the first ten to twenty seconds it is of an intense red (not *purple* as was originally stated), but fading rapidly while assuming a yellow tinge. In the second stage it is almost colorless, while the rods show a strong satin-lustre during thirty to sixty seconds. This lustre he found also in the retina of the pigeon where the red color was masked by the color of the oil globules. Hereupon the rods lose their lustre, swell and acquire the same index of refraction as the other layers, so that the retina becomes perfectly transparent. At the end of fifteen minutes the beginning post-mortem changes destroy this transparency.

The rapidity with which the retina is bleached depends on the intensity and color of the light. According to Kühne the rays of the spectrum between yellow and green possess the greatest influence, while the bleaching becomes slower as we proceed towards the violet end of the spectrum. Yellow rays have scarcely any action, red and ultra-violet (chemical) ones none at all. Hence experiments on the retinal red can be made most readily in the light of a monochromatic sodium flame, which destroys the color only in about two hours.

Exposure of the *living* frog to *sunlight* also bleaches the retina. When removed, at the end of five minutes, exposure in the living animal, it has become quite pale; in fifteen minutes the red color is destroyed, the lustre alone remaining (Boll). Mere daylight will bleach the living retina, only after a much longer time. On returning the animal into a dark box, the retinal red reappears in about one hour, and gains its greatest intensity in about two hours. Kühne found the color restored by darkness even in the exstirpated eye.

Of much interest is the action of the separate rays of the solar spectrum on the *living* retina. *Red* light renders the retinal tint darker, almost brown. In fading, when exposed again to ordinary light, it passes through a brownish-yellow stage. The color of the bluish-green rods is also intensified by red light. *Yellow* rays have no further action than rendering the color somewhat clearer. *Green* light, when of moderate intensity, or if intense—of short duration, changes the color to a purple-red, which when bleached by ordinary light, passes through a rosy tinge. A longer exposure to intense green light gives the retina a cloudy appearance, and if prolonged it finally bleaches it. The color of the bluish-green rods is, however, intensified and not as rapidly destroyed. The number of the bluish-green rods seems to be considerably *increased* by the action of green light, although Boll admits the uncertainty of such an observation. *Blue and violet* rays have about the same effect as green light. *Ultra-violet* rays are of no effect at all.

The anatomical separation of the retina from the choroid coat

succeeds most readily when the color has its maximum of intensity. Decolorized retinæ usually tear during this manipulation, and patches of pigment cells remain attached to them in the latter case. The following cause of this was discovered by Boll in eyes hardened with alcohol:

In the decolorized retina fine processes of the pigmented epithelium extend between the rods and cones up to the membrana limitans externa; in the colored retina no such processes are found.

Is the retinal red due to an optical arrangement, or to a chemical pigment?

On compressing the retina, there appears momentarily an intense green lustre, followed at once by decolorization. The retinal red is not affected by freezing, nor by the action of distilled water, glycerine, solutions of chloride of sodium, carbonate of sodium, acetate of lead or alum. All these experiments were of course made with sodium light. It is rapidly destroyed by boiling, by the action of alcohol, and caustic alkalies; less rapidly by ether and chloroform. Ammonia, by rendering the retina transparent, increases the brightness (and persistence) of the color. Alum (five per cent. solution), on the other hand, renders the retina hard and white; the posterior surface alone is found red. Acetic acid changes the retinal red to an intense golden-yellow, which fades but slowly. The dried retina also fades very slowly, until it has assumed an orange tint, when it is no longer sensitive to light.

The only *solvent* of the retinal red was found by Kühne to be bile, or a purified cholate. The filtered solution appears carmine, changing to buff on exposure to light. The red solution absorbs all rays of the spectrum between yellowish-green and violet; hence, the fresh retina appears gray or black, when illuminated by light of this color.

What is the source of the retinal red? The retina removed from an extirpated eye of a frog, is bleached at once; left *in situ*, it retains its color for hours. If partially detached from the choroid, Kühne found the detached portion of the retina soon bleached, while the other part remained red. On reapplying the detached retina to the choroid, its color was restored. The choroid is, hence, the source of the retinal red. If, on removing the retina, patches of the pigment-epithelium adhere to it, the corresponding spots are not bleached as rapidly. This is not due to the black color, since any other black background does not retard the bleaching. No red pigment, however, can be obtained by rubbing over the choroid with a piece of paper. The vital nature of the process may be shown besides by the action of heat. A temperature of 43° C. does not destroy the retinal red; if, however, the red has been previously bleached by light, a bath of that temperature prevents its regeneration, though the retina be left *in situ*. More light is shed on this obscure question by the observation of Boll, that the retinal

red, when rendered golden-yellow by the action of acetic acid, is identical in color with the oil-globules found in the retinal pigment-epithelium of the frog. In frogs kept in darkness, the epithelium contains only the ordinary golden-yellow oil-globules and a few smaller colorless oil-drops. If, however, the animal has previously been exposed to sunlight, and is examined during the period of regeneration of the retinal red, there is found constantly a large number of pale, yellowish oil-globules, the pigment of which has evidently been extracted. The—as yet unfinished—investigation of this pigment, made by Capranica, in Boll's laboratory, promises further interesting results.

The old question as to the possibility of obtaining persistent images on the dead retina, has been settled by these investigations. The readiest method, Kühne found, was to expose the freshly decapitated head of a rabbit to the light of one window (or to the light issuing from a window of ground-glass, in a dark box). On hardening the retina for twenty-four hours in a five per cent. solution of alum in the dark, a distinct white image of the window was found on the otherwise red posterior surface of the retina. By drying the retina, the specimen could be preserved. In bullock's eyes, Kühne could succeed in a similar manner, until one hour after death. In the latter case the image can be seen at once on spreading out the retina in a solution of salt. Optograms can also be thus obtained in curarized frogs.

Finally, the question arises, is the retinal red seen with the opthalmoscope? The color of the fundus of the eye is, no doubt, due to several factors: the color of the retina itself, and the vascularity of the choroid, covered, as it is, by the pigment-epithelium. At the moment of the death of a mammal, especially when from hemorrhage the fundus becomes paler. If now one eye is exposed to light, while the other is protected, the latter appears more of a buff, and quite different from the former, if examined with the opthalmoscope after the lapse of some minutes. (Helfreich, Boll.) On the other hand, Dietl and Plenk found that the fundus of a rabbit, which was still red, and seen with the ophthalmoscope, after death by hemorrhage, was whitened by injecting milk into the carotid artery. Still the retina, when removed, showed its red tint. The fundus of the frog appears always bluish-gray, whether the retinal red exists or is bleached. Boll thinks that this is due to the processes of the pigment-epithelium, which give the retina the optical character of a cloudy medium. If, however, the anterior half of the frog's eye is removed, the retinal red is seen, on looking obliquely at the retina. In mammals the retinal red is probably not the only source of the color of the fundus, inasmuch as we should expect the color of the retina to be but faint in an eye long exposed to day-light. In fact, Boll states, that the human fundus shows the deepest red color in the morning, before the eye has been exposed to day-light. H. GRADLE.